Attachment #1 to
OXC-1019

IONIZATION PROGRAM

In December 1959 a program was initiated to investigate the use of
an ionized gas in the jet of an afterburning turbojet engine. A
J57 engine was set up on a sea level test stand and attenuations
were measured both with and without ionizing materials added. The
materials used were salts of sodium, potassium, and cesium dissolved
in alcohol.

The results obtained in the sea level tests indicated that satis-
factory levels of attenuation could be achieved but attempts to
analytically predict metal flows at altitude resulted in flow rates
that were of such a wide range of values as to be completely unbe-
lievable. It was suspected that this wide range of predicted metal
flows as due to:

    1. An effective temperature function which resulted
       in lower ionization potentials than the known
       potentials of the material being tested.

    2. Lack of appreciation for the effect of density
       (collision frequency).

Accordingly, a J57 engine was set up in the Willgoos Laboratory at
East Hartford. Object of this test was to provide an additional
step in the density temperature spectrum to improve our ability
to predict metal flows at the cruise conditions.

Since the Willgoos Lab could not physically produce the tempera-
tures and densities which would be experienced at maximum high
altitude cruise, a scale test was set up in the UAC Laboratory
using a JT-3 burner and jet nozzles sized to produce the densities
and temperatures which will be experienced at altitude cruise
conditions.

While these tests were being set up, it was decided by all parties
concerned that in addition to attenuation, phase shift should be
measured in order to get a better feel for plasma frequency, col-
lision frequency and, by analysis effective temperatures.

The Willgoos Lab tests have been completed and some of the low
temperature tests at the UAC Lab have been completed.

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Following is a listing of:

    1. Objectives
    2. Results of the data now in hand in terms of things
       we think we know.
    3. Questions not resolved.
    4. Future program to be completed.

It should be noted that these comments are concerned only with the problem directly at hand, that of providing an ionized plug in the tail pipe of a jet engine.

Some of the things that have been learned can be applied to the general field of plasma physics but we do not propose that under this program these should be followed beyond the point necessary to accomplish the present task.

Some side effects which may be important to other means of detection have been noted. These are mentioned as a matter of record and are being accessed by the appropriate group in the program.

As a part of this review, we have not entered into any discussion of the hardware involved on either the engine or the aircraft.

Signed by:

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1. Initial Objectives

1. To determine if ionization of sufficient levels to conceal the engine outlet could be produced in a jet engine afterburner exhaust.

2. To determine the best material for producing this ionization.

3. To produce this ionization over the full range of afterburning at altitude.

4. To acquire sufficient data to permit prediction of required metal flows vs. altitude and temperature.

5. To determine the amount of ionizing material required to be carried per engine on an aircraft performing a specific mission.

2. Ixcon

1. 20#/hr. cesium in a 1 meter dia. flame will produce $f_o = 1000$ or more, at the exit plane of a J57 engine. When operating at a density approximately equivalent to 11×10^{-5} slugs/cu. ft. and at calculated static temperatures of $2000°F$.

2. 2.0#/hr. cesium in a 10" dia. flame will produce $f_o = 1000$ or more at the exit plane when operating at a density approximately equivalent to 2.5×10^{-3} slugs/cu. ft. and at a calculated static temperature of $1400°R$. (This was accomplished in the UAC Lab).

3. Of the materials tested, cesium appears to have significant advantages over potassium and sodium in terms of providing the desired ionization levels, however, there may be some other means, such as availability, handling, etc., which may make potassium a desirable material to use. Therefore, potassium will continue to be considered.

4. If calculated static temperatures are used, and equilibrium conditions are assumed, the use of the Saha equation predicts ionization levels which are much lower than those observed.

   Reasons for this variance are as follows:

   a. Equilibrium probably does not exist; therefore, static temperature is not a true measure of the probability of ionization.

   b. The electron temperature is suspected to be higher than the static temperature by a factor of several hundred per cent.

2. 5. A high confidence level can be assigned to the measure-
ments made because collision frequencies agree within
reasonable limits with values of collision frequency
determined by other methods and other experimenters.

6. Based on the data achieved to date and applying cor-
rections for the difference between the test jets and
the J58 jet, the following flow rates and total metal
weights based on pure cesium metal would apply:

	Max A/B	Min A/B	Tot. 2 Hr Mission Reqt.
$f_o = 100$	1.8#/hr	7 #/hr	6.5#/engine
$f_o = 500$	7.2	36 #	30#
$f_o = 1000$	14	70 #	60#

This is based on the use of the most conservative correc-
tion factors applied to Willgoos Lab data. Therefore,
using a conservative estimate of temperature gradient,
the maximum pure metal required can be as high as 60#
and
using the most optimistic estimate of temperature grad-
ient, as low as 6.5# per engine per mission.

3. Questionable Areas

1. What is the rate of effective temperature deterioration in
the jet plume?

2. What is the ultimate goal of f_o at the exit of the tail
pipe? This is a function of deterioration rate noted above
and the basic goal of $f_o = 100$ at 1 dia. downstream of the
exit.

3. What is proper carrier for ionisation material and what
physical hardware is required in the airframe and engine?

4. Future Program

1. Complete tests currently planned for UAC Research Laboratory
which are directed at more clearly defining the effects of
additives at the exit plume under the other engine operating
conditions.

2. Examine spectrographically the emission spectrum of the
flame with and without additives. Conclusions as to the
electron temperature, and the proper distribution function
with which to describe the atomic state can be drawn from
these measurements.

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4. 3. Investigate the possibility of setting up a test by minor
modification to UAC equipment to investigate effects of radiation and change of state, as a function of the distance
from the exit plane.

    4. Make a spectrographic examination of jet plumes of J58 and
J57 engines at sea level.